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ORNL/TM-2016/240

# Light Water Reactor Sustainability Program:

# Report on the Harvesting and Acquisition of Zion Unit 1 Reactor Pressure Vessel Segments

**June 2016**

**Prepared by**

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**Light Water Reactor Sustainability Program**

# Report on the Harvesting and Acquisition of Zion Unit 1 Reactor Pressure Vessel Segments

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## ACKNOWLEDGMENTS

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## EXECUTIVE SUMMARY


The decommissioning of the Zion Units 1 and 2 Nuclear Generating Station in Zion Illinois presents a special and timely opportunity for developing a better understanding of materials degradation and other issues associated with extending the lifetime of existing nuclear power plants (NPPs) beyond 60 years of service. In support of extended service and current operations of the US nuclear reactor fleet, the Oak Ridge National Laboratory (ORNL), through the Department of Energy (DOE), Light Water Reactor Sustainability (LWRS) Program, is coordinating and contracting with Zion Solutions, LLC, a subsidiary of Energy Solutions, an international nuclear services company, the selective procurement of materials, structures, components, and other items of interest from the decommissioned reactors as well as possible access to perform limited on site testing of certain structures and components.

The LWRS Program, and other interested research organizations (e. g., the Electric Power Research Institute (EPRI) Long-Term Operation (LTO) Program and the U.S. Nuclear Regulatory Commission (NRC) wish to acquire materials from Zion to evaluate potential materials degradation issues associated with extended lifetime of existing nuclear power plants. This report describes the acquisition and shipment by rail of four segments of the Zion Unit 1 RPV to the Energy Solutions Memphis Processing Facility (MPF) for eventual laboratory testing. Specifically, Segment 1 of the Zion Unit 1 reactor pressure vessel (RPV) containing well-characterized base metal heat B7835-1 and a section of the well-characterized WF-70 beltline weld (between the lower and the intermediate shells) was harvested and shipped for cutting into blocks for machining into mechanical test specimens and microstructural characterization samples at a third vendor. Access to service-irradiated RPV welds and plate sections will allow through-wall attenuation studies to be performed, which will be used to assess current radiation damage models [1, 2].

Although the original plan focused on the acquisition of two adjoining segments, (Segments 1 and 2), to maximize the peak fluence volume of the beltline weld available for testing, four segments, packaged into two steel boxes were acquired because the segmentation process required opposing segments (1 and 5 and 2 and 6) be cut to maintain the balance of the remaining RPV and to use those opposite segments as shielding when placed in the shipping boxes. Moreover, prior to shipment of the segments, the plan was further modified to cut blocks and machine specimens from only one segment (Segment 1) to reduce cutting and machining costs while acquiring sufficient samples for planned testing. The three remaining segments and cutting waste will be shipped to the Energy Solutions, Clive Utah site for disposal. Only the cost to ship and bury the cutting waste and the differential cost to ship the three unused segments from Memphis to Clive compared with shipping those segments from Zion to Clive will be incurred by the LWRS Program.

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# 1. INTRODUCTION

## 1.1 BACKGROUND

It is well known that components and structures in a NPP must withstand a very harsh operating environment, including extended time at temperature, under stress from operational loads, under neutron irradiation, and in corrosive media. Moreover, extending reactor service beyond 60 years will increase those demands and possibly introduce new modes of degradation [3]. Although the numerous modes of degradation are complex and vary depending on location and material, understanding and managing materials degradation is key for the continued safe and reliable operation of NPPs. As noted in the Expanded Materials Degradation Assessment (EMDA) [4], a comprehensive evaluation of potential aging-related degradation modes, an important component of understanding materials degradation is the examination of service-aged materials. And one important source of service-aged materials has been the Zion Harvesting Project [1]. This project is important because access to materials from active or decommissioned NPPs provide an invaluable resource for which there is limited operational data or experience to inform relicensing decisions and assessments of current degradation models to further develop the scientific basis for understanding and predicting long-term environmental degradation behavior.

*The Zion Harvesting Project*, in cooperation with Zion Solutions, LLC, a subsidiary of Energy *Solutions,* an international nuclear services company, is coordinating the selective procurement of materials, structures, components, and other items of interest to the LWRS Program, ERPI, and NRC from the Zion Station (a former nuclear generating facility), in support of extended service and current operations of the U.S. nuclear reactor fleet. The Zion Station is a decommissioned two unit, Westinghouse 4-loop PWR facility, with each unit capable of producing 1,040 MWe. The units were commissioned in 1973, permanently shut down in 1998, and placed into SAFSTOR (a method of decommissioning where a nuclear facility is placed and maintained in a condition that allows the facility to be safely stored and subsequently decontaminated to levels that permit release for unrestricted use) in 2010. Materials of high interest include low-voltage cabling, concrete core samples, through-wall-thickness sections of the RPV, and other structures and components of interest to researchers evaluating aging management issues [4].

A potentially life-limiting component in light-water reactors (LWR) is the RPV because replacement of the RPV is not considered a viable option [1]. Researchers studying the effects of radiation on RPV materials have long been interested in evaluating service-irradiated materials to validate physically-informed correlations of transition-temperature-shift predication models [5]. For those reasons, the LWRS Program proposed the acquisition of segments of the Zion Station Unit 2 RPV, cutting the segments into blocks from the well-characterized beltline weld [6 - 8] and base metal [12], and machining those blocks into mechanical (Charpy, compact tension, and tensile) test specimens and coupons for microstructural (transmission electron microscopy, atom probe tomography, small angle neutron scattering, and nano indention) characterization.

This report documents the Zion RPV Phase 1: the acquisition and shipment, by rail, of four segments of the Zion Unit 1 RPV to the Energy Solutions Memphis Processing Facility (MPF) for eventual laboratory testing of through wall samples. Specifically, Segment 1 of the Zion Unit 1 RPV containing well-characterized base metal B7835-1 heat and a section of the well-characterized WF-70 beltline weld (between the lower and the intermediate shells) was harvested and shipped to the MPF for cutting into blocks (Zion RPV Phase 2), which will be machined into mechanical and microstructural characterization samples (Zion RPV Phase 3) at a third vendor Access to service-irradiated RPV welds and plate sections will allow through-wall attenuation studies to be performed, which will be used to assess current radiation damage models. [1, 2]

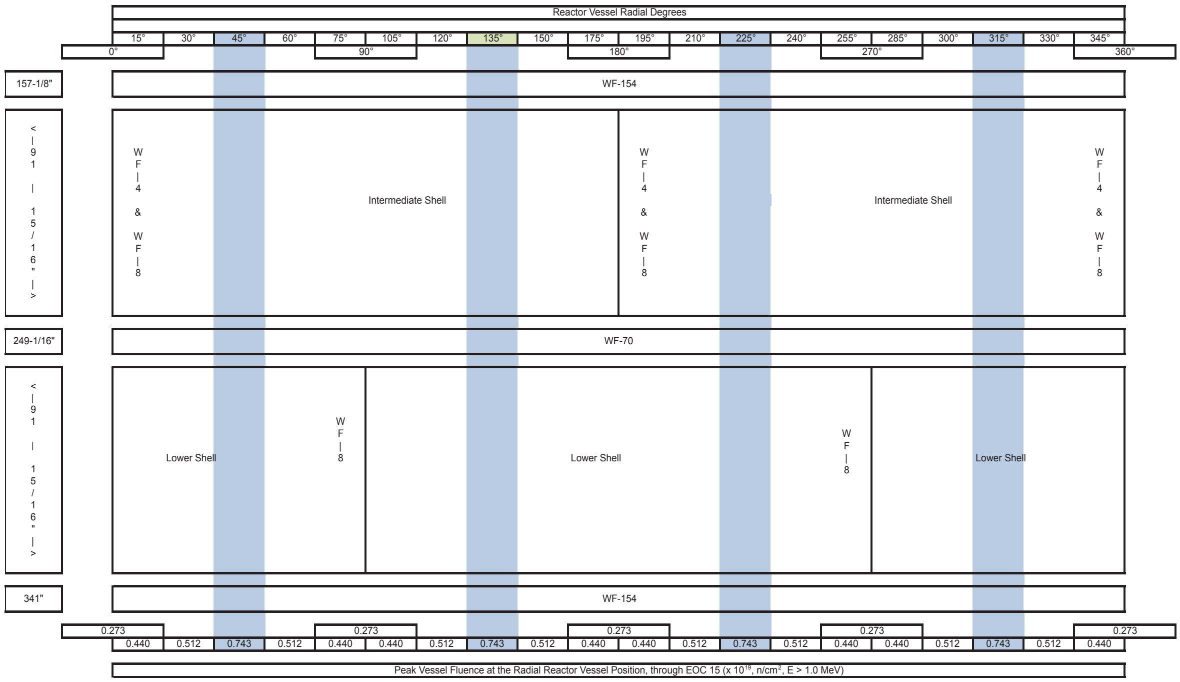


**Figure 1.** Peak vessel fluence along the circumferential weld of the Zion Unit 1 RPV through End of Cycle (EOC) 13 (x $10^{19}$ n/cm$^2$, E > 1.0 MeV) [9].

## 1.2 CIRCUMFERENTIAL FLUENCE

An important consideration in the evaluation of which RPV segments to harvest is the circumferential fluence. As shown at the bottom of in Figure 1, peak circumferential fluence varies by a factor of three over a 45° arc from the vertical weld positions to midway between the vertical weld positions. *Based on this variation, the optimum region of beltline weld to harvest would be a section midway between the upper (intermediate shell) and lower (lower shell) vertical welds.*

## 1.3 RPV SPECIFICATIONS

The Zion RPV has a total height without the head plate of approximately 419 inches (1,064 cm). The vessel wall has an inner diameter of 173 inches (439 cm) and thickness of 8.8 inches (22.4) cm) over the beltline region. The nozzle section is approximately 11 inches thick. Including cladding, the reactor vessel weighs about 700,000 lbs. (3,182 kg) and has a total activity of about 400 curies. The characterization results indicate that the vessel wall is class A waste.

The stainless steel cladding has a nominal thickness of 3/16 inch (~ 5mm). The total weight of the cladding within +/- 2 feet of the core is about 4,750 lbs (2,159 kg) and has a total activity of approximately 145 curies. If it were separate from the vessel wall, the cladding would be class B waste, but if it is integral with the ferritic steel wall, the assembly as a whole is class A. The RPV is composed of the head, nozzle ring section, three ring or shell sections composed of hemispherical plates with two vertical welds, and a bottom plate as shown in a preliminary segmentation plan with horizontal cuts along the three ring sections (nozzle, middle shell, and lower shell) and the bottom plate (Figure 2).

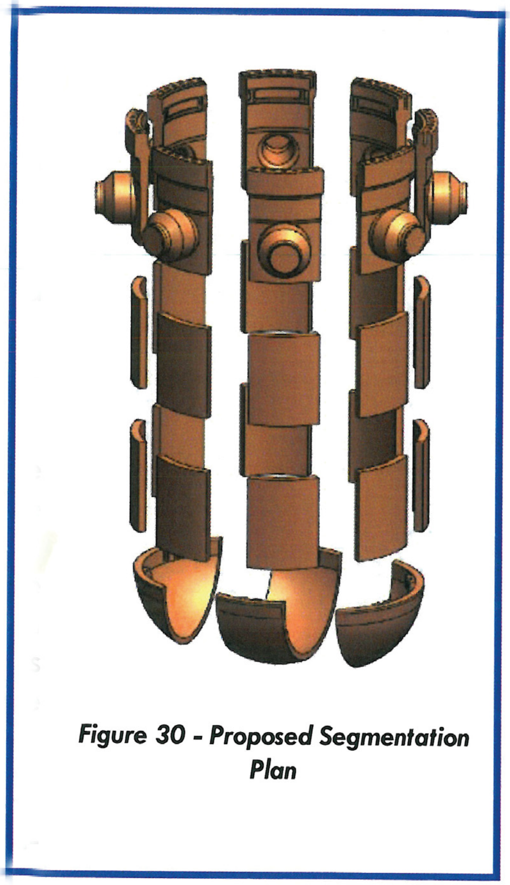


**Figure 2**. A preliminary schematic of the RPV segmented by ring sections and the bottom plate.

## 2. SEGMENTATION PLAN

**Segmentation Plan:** Based on information provided by Mr. Dan E. Pryor, Manager, Reactor Vessel Segmentation, Zion Solutions, the vessel was cut, using an oxy-propylene torch into 17 segments over four levels (Figure 3 and Figure 4). Level l, which includes the inlet and outlet nozzles, was cut into eight 45°segments of 157.5" (400 cm) in height. Level 2 was also cut into eight 45°segments of 157.5" (400 cm) in height and 72.9" (185.2 cm) in length as measured from end to end of the outer diameter. Because the vessel could not be rotated 22.5° after the nozzle segments were cut due to the location of the overhead bridge, the level 2 segments, which include most of the intermediate shell and a portion of the lower shell and the well-characterized WF-70 beltline weld, the vertical cuts were made along the same lines as the vertical nozzle cuts, i. e, at the two vertical welds of the intermediate shell, directly above the vertical welds of the lower shell, and in the middle of the peak circumferential fluence. Moreover, four segments (1, 2, 7, and 8) also contained the well-characterized base metal B7835-1 in the upper shell (Figure 4, Figure 5, and Figure 6). The beltline pieces cut from the vessel are 8.8 inches thick including a 3/16th inch stainless steel cladding on the internal surface. Each piece weighs approximately 28,000 lbs. (12,727 kg).

Since the Level 2 horizontal cuts occurred at elevations 157.5” (400 cm) and 315” (800 cm), the later, which is significantly below the circumferential weld of the upper and intermediate rings and just above the radial guides on the inside of the vessel that will be used to support the vessel during segmentation, there was no thermal damage to the beltline weld or heat-affected zone from the horizontal cuts.

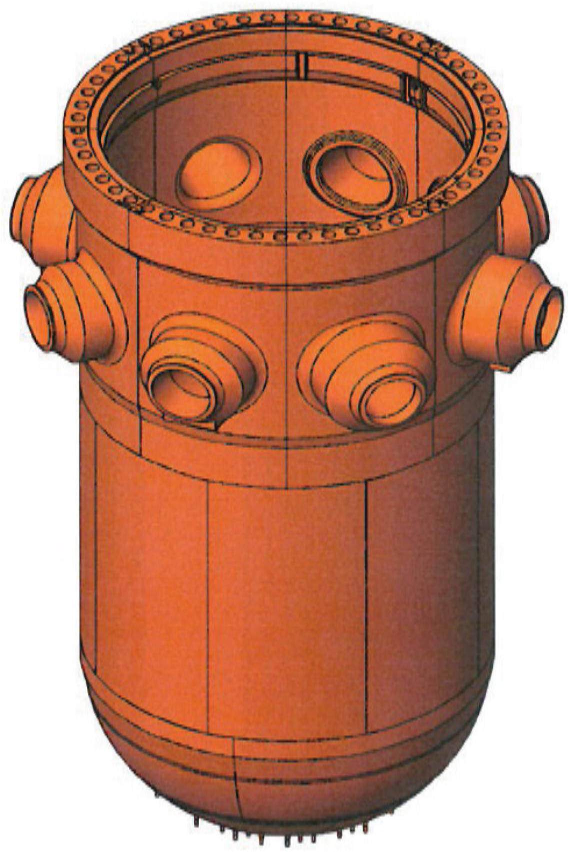


**Figure 3.** An isometric view of the 2014 Zion RPV segmentation plan [10].

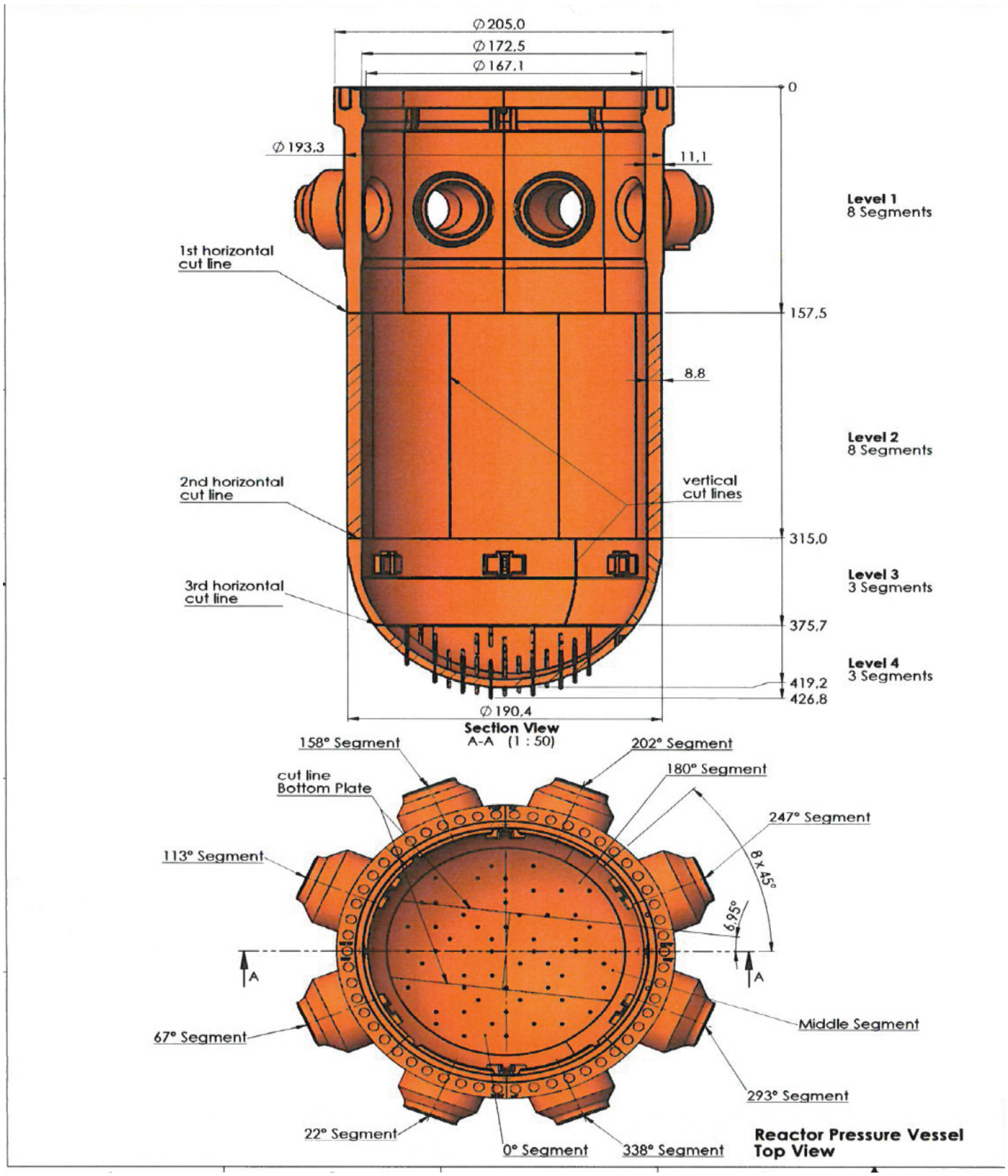


**Figure 4.** The 2014 RPV Segmentation Plan for the Zion Unit 1 vessel. The black lines are the proposed cut plan. There are eight vertical cuts in the nozzle region and eight vertical cuts in the Level 2 intermediate and lower shell area [10].

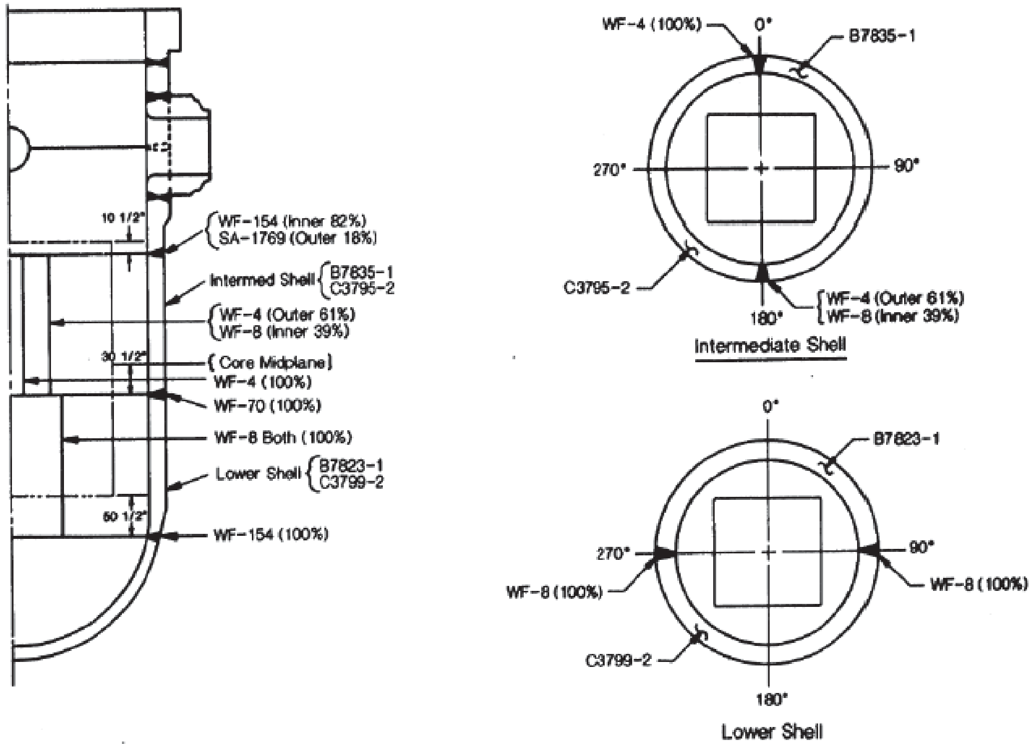


**Figure 5.** Location of materials (weld and base metal) used in the fabrication of the Zion Unit 1 beltline (intermediate shell to lower shell), two vertical welds above the beltline, and base metal heats [11].

# 3. HARVESTING OBJECTIVES, SCOPE, AND TASKS

## 3.1 OBJECTIVES

The initial objective of this work was to acquire two segments of the Zion NPP Unit 1 RPV. Specifically, to harvest a segment containing the well-characterized WF-70 beltline weld and the well-characterized base metal heat B7835-1 and an adjoining section, with the same beltline and base metal materials, that overlaps one of four high circumferential fluence regions along the vertical cut (Figure 3, Figure 4, Figure 5, and Figure 6). *Due to the estimated costs to cut 8 blocks from two segments and machine specimens from 5 of the blocks, a revised objective was developed, after the segments had been loaded into boxes, to obtain only one segment (Segment 1) of the Zion NPP Unit 1 RPV and to cut seven blocks and to machine four of the blocks into WF-70 beltline weld and base metal B7835-1 specimens for laboratory testing.* Data from surveillance specimens containing similar WF-70 weld materials and base metal B-7835-1 are available in the literature for a comparison of hardening and changes in fracture toughness [12].

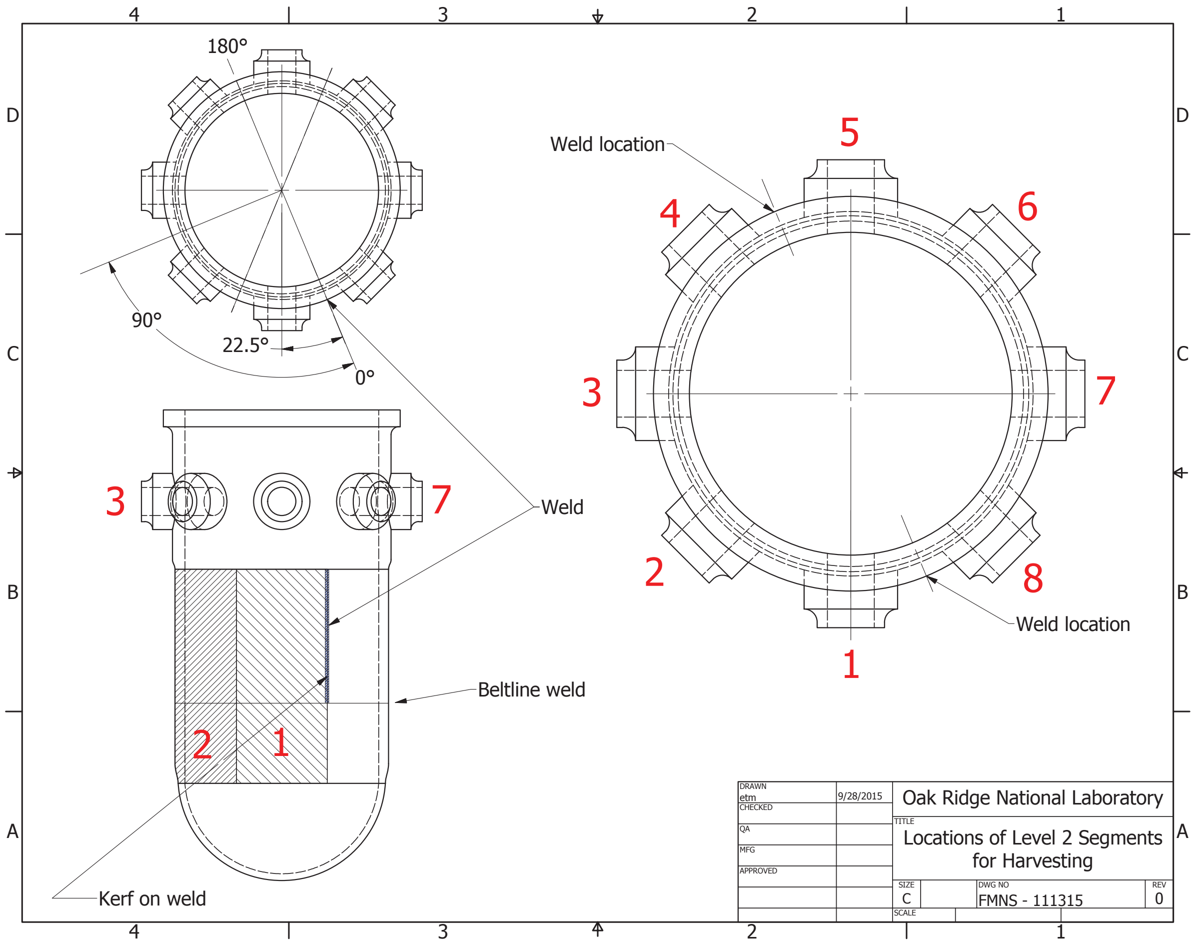


**Figure 6.** Identification of Level 2 segments (1, 2, 5, and 6) collected as part of process to harvest Segment 1. Segment 1 (as well as Segments 2, 7, & 8) contains the well-characterized base metal B7835-1 (intermediate shell) and a section of the well-characterized WF-70 beltline weld [10].

### 3.2 SCOPE

Harvest two adjoining segments sharing the high circumferential fluence regions along the vertical cut and containing the WF-70 beltline weld and base metal heat B-7835-1 from the Zion Unit 1 RPV. The right edge of the first segment (as viewed from the outside of the RPV) begins at the 0° position / WF-4 vertical weld and the left edge of the second ends at the 90° position. As previously discussed, the original plan called for the acquisition of two adjoining segments, (Segments 1 and 2), to maximize the peak fluence volume of the beltline weld available for testing. This required the acquisition of four segments, packaged into two steel boxes, because the segmentation process required opposing segments (1 and 5 and 2 and 6) to be cut to maintain the balance of the remaining RPV and to use those opposite segments as shielding when placed in the shipping containers. Moreover, as noted above, prior to shipment of the segments, the Harvesting (Phase 1), Cutting (Phase 2) and Machining (Phase 3) plan was further modified to cut blocks and machine specimens from only one segment (Segment 1) to reduce Phase 2 (cutting) and Phase 3 (machining) costs while acquiring sufficient samples for planned testing.

## 3.3 TASK 1

**Harvest ORNL BW1 RPV Segment:** Verifying that the RPV did not rotate a few degrees after cutting and removal of the nozzle shell segments, as occurred during the segmentation of Zion Unit 2 RPV and which would rotate the location of maximum fluence, harvest one segment (Segment 1, Figure 4, Figure 5, and Figure 6) containing base metal B7835-1 and a section of the WF-70 beltline weld (between the lower and the intermediate shells). The right edge (as viewed from the outer wall) of this segment begins at the 0° position / WF-4 vertical weld. This segment is paired with Segment 5 (Figure 4, Figure 5, and Figure 6) to provide shielding during shipping.

The process used to obtain Segment 1 was as follows:

a) The beltline weld was located on the outer wall of the RPV and photographic evidence of the location of the segment provided as shown in Figure 10 and Figure 11.

b) Segments, ~ 13' x 6' (157.5" x 72.9" x 8.8") of the RPV extending from just below the circumferential weld between the nozzle section and the intermediate shell to just above the circumferential weld between the lower shell and the bottom plate were cut using an oxy-propane torch (Figure 7). Specifically, a series eight of "L"- shaped vertical and horizontal cuts were performed in sequence around the circumference of the Zion Unit Level 2 region followed by a final horizontal notch cut to separate adjoining segments. The notch cuts were performed on opposing segments (e.g., 1 and 5 and 2 and 6) to maintain the balance of the RPV and to use those opposite segments as shielding when placed in the shipping container boxes. The selected segment, Segment 1 (Figure 6 and Figure 10), contains base metal B7835-1 and a section of the WF-70 beltline weld. The right edge (as viewed from the outer wall of the RPV) begins at the 0° / WF-4 vertical weld. And as previously discussed, this selection assumed that the RPV did not rotate a few degrees during the cutting and removal of the nozzle segments (Figure 4).

**Figure 7.** Oxy-propane torch performing a vertical cut of a Level 2 Segment from the Zion Unit 1 RPV [10].

c) The cut segment (Segment 1) was removed using a gripper crane and positioned onto the down-ender frame (Figure 8) to allow proper positioning in the shipping box. The first segment is loaded face up and the matching (opposite side segment) is loaded face down to provide clam-shell shielding as shown in Figure 9 and Figure 10 in the same manner as used to ship the other RPV sections to the Energy Solutions, Clive, Utah site.

**Figure 8.** Gripper crane and down-ender frame for repositioning segments into the shipment box [10].

**Figure 9.** Loading the matching (opposite side segment) face up into the shipping container box [10].

**Figure 10.** Zion Unit 1 Level 2 Segment 1 loaded into the steel shipment box [10].

**Figure 11.** Zion Unit 1 Level 2 Segment 2 loaded into the steel shipment box [10].


**Figure 12.** Closing the steel box containing opposite side segment pairs for shielding and eventual loading into the rail car [10].


**Figure 13.** Crane used for loading two steel shipping container boxes holding 2 each Zion Unit 1 RPV Level 2 segments into the railcar. The railcar arrived at the Energy Solutions MPF on April 12, 2016.

## 3.4 TASK 2

**Harvest ORNL BW2 RPV Segment:** Verifying that the RPV did not rotate a few degrees after cutting and removal of the nozzle shell segments, in a similar fashion as occurred during the segmentation of Zion Unit 2 RPV and which would rotate the location of maximum fluence, harvest one segment (Segment 2, Figure 4, Figure 5, and Figure 6) containing base metal B7835-1 and a section of the WF-70 beltline weld (between the lower and the intermediate shells). The right edge (as viewed from the outer wall) of this segment begins at 22.5° and ends on the left edge at 45°. This segment was paired with Segment 6 (Figure 4, Figure 5, and Figure 6) to provide shielding during shipping. The process used to cut, harvest, and package Segment 2 for shipment to the Energy Solutions MPF was identical that used in Task 1 for Segment 1.

# 4. NON-DESTRUCTIVE EVALUATION

**Non Destructive Evaluation of RPV Segments:** As a result of the unique opportunity to evaluate large segments of the RPV, non-destructive examination of near surface flaws prior to cutting the beltline and vertical weld segments into smaller pieces for machining into mechanical test and microstructural characterization specimens was evaluated as an option but funding from other interested parties, such as EPRI and NRC, was not made available.

# 5. TRANSPORTATION OF ZION RPV SEGMENTS

**Transportation of Segments:** Due to the size and weight of the four Zion Unit 1 RPV Level 2 beltline sections, (~ 13' x 6' 157.5" x 72.9" x 8.8" thick including a 3/16 in SS cladding on the internal surface, weighing ~ 28,000 lbs. each) in two large steel boxes with a combed weight of ~ 180,000 lbs, a rail car was used to ship the RPV segments to the Energy Solutions, MPF site on March 31, 2016 for cutting Segment 1 into blocks for eventual machining. On April 12, 2016, the railcar containing the four segments arrived at the Energy Solutions MPF site and was received, inspected, and temporarily stored while a revised contract with the Energy Solutions for cutting seven blocks from the Zion Unit 1 RPV Segment 1 is finalized. The target date for starting the cutting phase of the project is June 13, 2016.

Once the "Block Cutting" contract (Zion RPV Phase 2) is in place, the box containing Zion Unit 1 RPV Segments 1 and 5 will be transferred from the rail car to the designated C-zone cutting location, the segments identified, and the activity verified. As soon as this is completed, Segment 5 will be stored in the steel box along with the box containing Segments 2 and 6 for along with the Segment 1 cutting waste for eventual shipment as waste to Clive, Utah.

## 6. BLOCK CUTTING PLAN

**Objectives for Cutting the Segments into Blocks for Machining:** The objective is to cut one segment **(ORNL BW 1**) of the Zion NPP Unit 1 RPV into 7 blocks of welds and base metal and to package those blocks for shipment to a vendor that will machine the blocks into test specimens including Charpy V-Notch (CVN), tensile, and fracture toughness. The cutting waste and remaining unused segments will be packaged and shipped to the Energy Solutions, Clive, Utah site.

**Scope:** One RPV segment harvested from the Zion Unit 1 NPP that includes the WF-70 beltline weld, **ORNL BW1 RPV Segment** (Figure 4, Figure 5, and Figure 6) shall be cut into blocks (Figure 14 and Figure 15) varying in length from approximately 5.7 x 2.0 x 8.5 inches to 7.6 x 3.0 x 8.5 inches to 11.25 x 3.0 x 8.5 inches. Three types of blocks shall be cut and are designated as "**C**," "**F**," and "**CF**.". The "**C**" block is designated for machining Charpy V-notch, SS-3 tensile specimens and coupons for chemical and microstructural characterization. The "**F**" block is designated for machining compact tension specimens for **F**racture toughness testing. The "**CF**" block is designated for alternating rows of Charpys and compact tension specimens.

**Task 1 Identification of the welds:** Prior to cutting the "**C**," **"CF,"** and "**F**" blocks, the location of the center line of the welds shall be identified using chemical etching or other suitable techniques on the outer wall of the segment. An ORNL technical representative will be on site to assist Energy Solution MPF staff in the identification of the weld.

**Task 2: Beltline Weld BW1 RPV Segment Cutting Plan:** Two "**C**" blocks, one **"CF"** block and four "**F**" blocks shall be cut from **ORNL BW1 RPV Segment** (Zion Solutions RPV Segment 1 Figure 6**)** containing a portion of the WF-70 beltline weld and base metal heat B7835-1 and no vertical weld (Figure 14 and Figure 15).

- One "**CF**" block (11.25 x 3.0 x 8.5 inches) and one **"C"** block (7.6 x 3.0 x 8.5 inches each), separated only by the kerf, shall be cut from and centered on the WF-70 beltline weld. The **"CF"** block shall be cut ~ 4" from the left edge of the vertical cut, as shown in Figure 14 and Figure 15. The "**C**" block (7.6 x 3.0 x 8.5 inches) and four "**F"** blocks (5.7 x 2.0 x 8.5 inches each), separated only by the kerf, shall be cut from the base metal above the beltline weld **"CF"** block that is located closest to left vertical edge of the segment as viewed from the external side of the RPV segment and ~ 4" (depends upon actual vertical cut location) from the left edge. The first **"C"** block cut from the base metal shall be at least 2" above the beltline weld "**CF**" block.
- An ORNL technical representative will be on site to assist Energy Solutions MPF staff in the identification of the weld to insure that the block is centered on the weld.
- The Vendor shall use the most cost and time effective methods to reduce excess material from the segment prior to final cutting of the 4 "**F**," 2 "**C**" blocks, and "**CF**" block.
- Each of the seven (7) blocks shall be uniquely numbered for identification, orientation, and tracking.

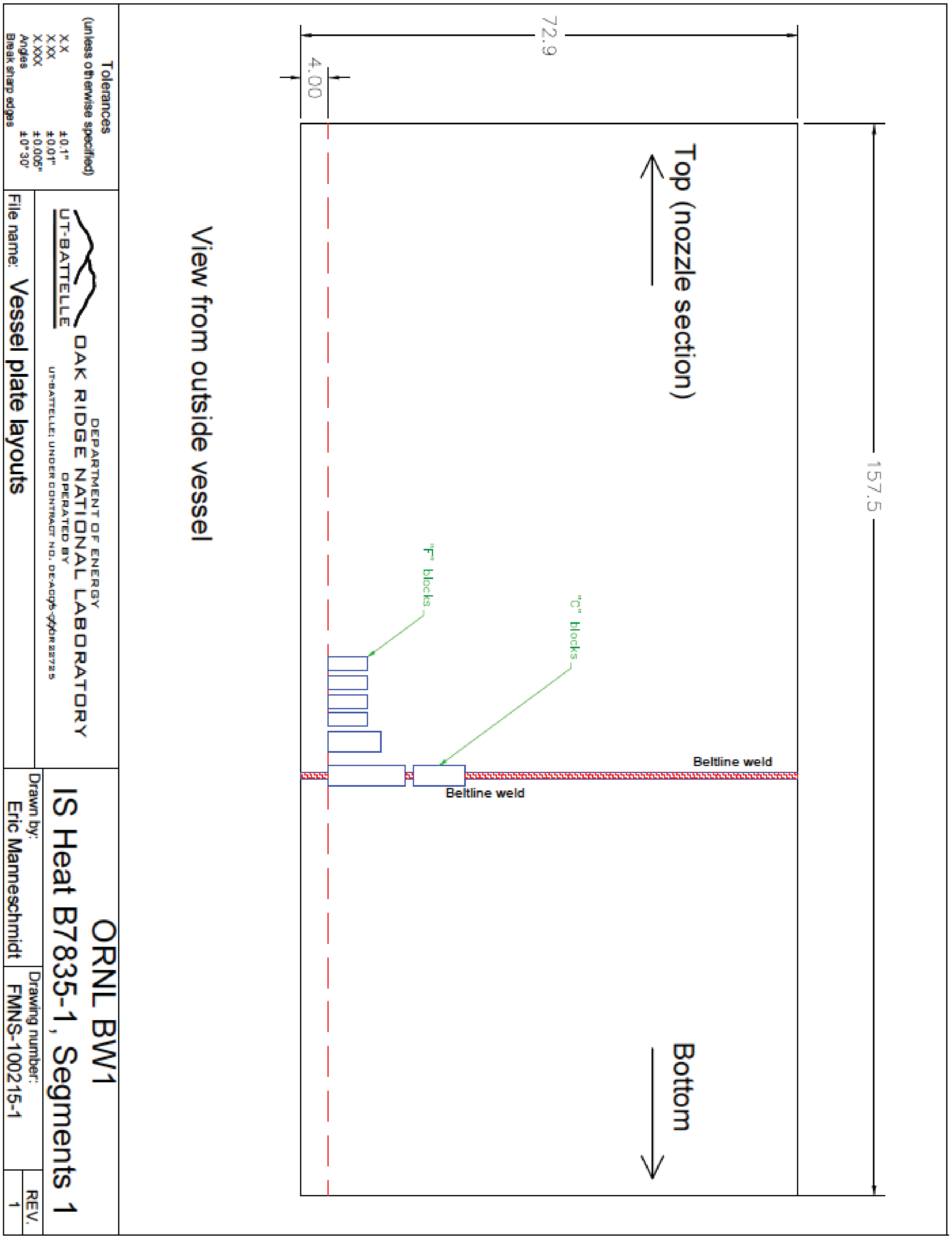


**Figure 14.** Cutting plan for the Zion Unit 1 RPV (**ORNL BW1**) segment (ZS Segment 1 or 3) that contains only the beltline weld and base metal heat B7835-1 (See Figure 4, Figure 5, and Figure 6).

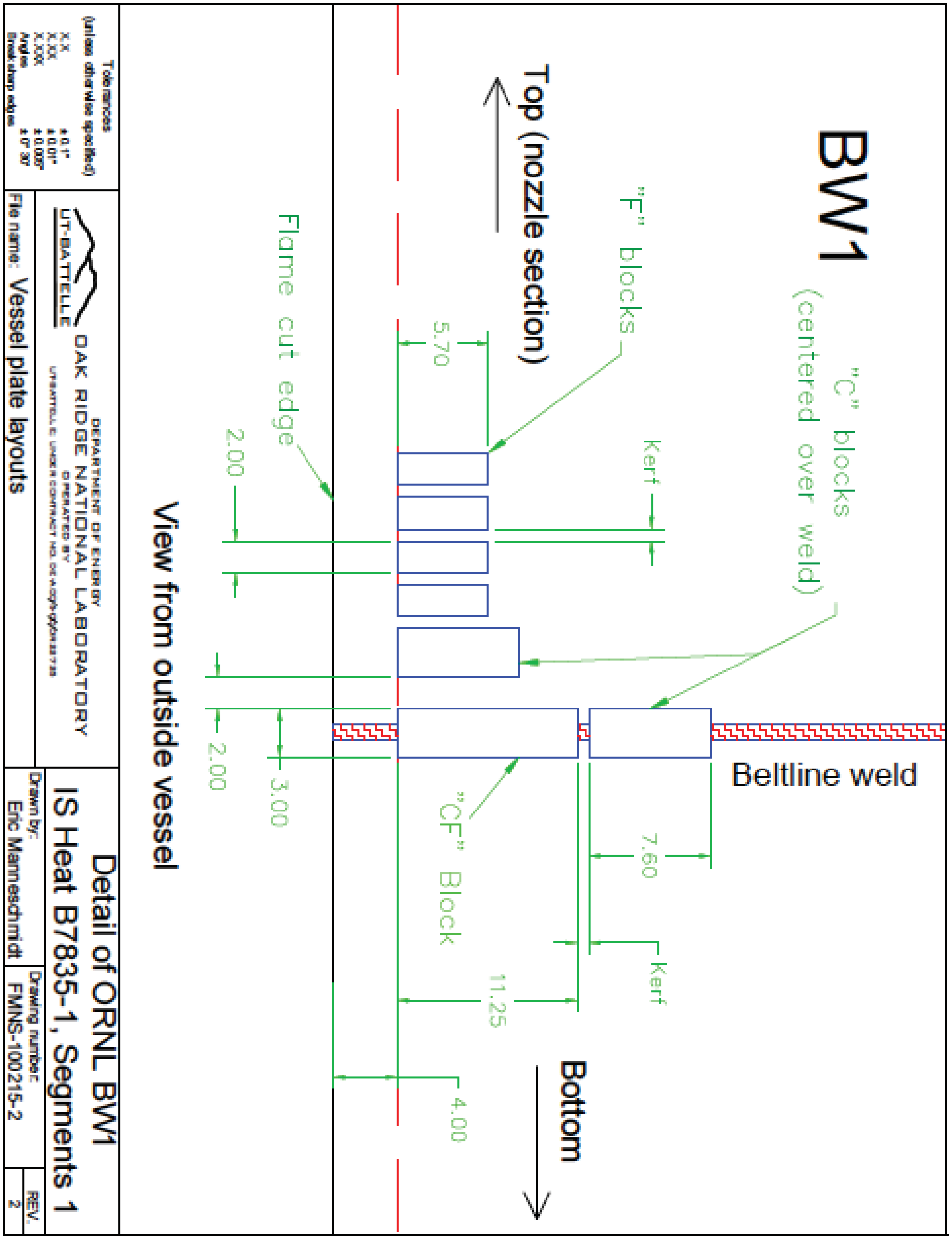


**Figure 15.** Expanded view of the cutting plan for the Zion Unit 1 **ORNL BW1 RPV Segment 1** that contains only the beltline weld and base metal heat B7835-1 (See Figure 4, Figure 5 and Figure 6).

## 7. REVISED MACHINING PLAN SUMMARY

The summary of the revised machining plan for one (1) base metal **"C"** block, one (1) beltline weld **"CF"** block, and two (2) base metal **"F"** blocks is listed below.

**Summary of samples to be machined from one "C" block (base metal)**

239 = [(17x15)-16] Charpy specimens
128 = (16 x 8) SS3 tensile specimens
64 = (2 x 2 x 16) coupons (for microstructural characterization)

**Summary of samples to be machined from one "CF" block (weld)**

180 = (20 x 9) Charpy specimens
144 = (9 x 2 x 8) SS3 tensile specimens
72 = (2 x 2 x 18) coupons (for microstructural characterization)
80 = (10 x 8) 0.4T C(T)

**Summary of samples to be machined from 2 "F" blocks (base metal):**

112 = 56 (4 x 14) 1/2 T C(T) x 2 "F" blocks

**Summary of samples to be machined by type:**

Charpy specimens (239 base metal + 180 weld) = **419**
SS3 tensile specimens (128 base metal + 144 weld) = **272**
Coupons (64 base metal + 72 weld) = **136**
Fracture toughness (112, 1/2T base metal + 80, 0.4T weld) = **192**

## 8. PRELIMINARY TEST PLANS

**Through Wall Attenuation Study of Welds and Base Metal Test and Research Plan:** The through-wall mechanical test specimens, including Charpy V-Notch (CVN), tensile, and fracture toughness, machined from the beltline WF-70 weld and based metal heat B7835-1, having a peak fluence < 1 x $10^{19}$ n/cm$^2$ will be tested to evaluate the change in mechanical properties as function of depth (neutron fuence attenuation).

The specimen dimensions will be as follows:

- CVN (Charpy V-Notch) / Size: 10 x10 x 55 mm
- Tensile / Size: 10 x 10 x 55 mm or smaller, and
- Fracture toughness (compact tension) / Size: ½-T C(T) and 0.4 TC(T)

In addition to specimens for mechanical testing, through-thickness chemical characterization (at least, Cu, Ni, Mn, P), hardness distribution, and various microstructural characterization techniques such as Atom Probe Tomography (APT), Small Angle Neutron Scattering (SANS), and Positron Annihilation Spectroscopy (PALS) will be performed.

The test plans are as follows:

1. Determine the through-thickness variation in chemical composition of the weld (especially Cu).

2. If the chemical composition, especially the Cu content, is relatively uniform, perform CVN and tensile tests and compare results with surveillance results.

3. Perform CVN (see Fig. 16), tensile, hardness, and $K_{Jc}$ testing through thickness to evaluate attenuation effects.

4. Microstructural characterization (Atom probe, SANS, SEM, TEM, and nano indention) will be performed through thickness to evaluate attenuation effects using specimens obtained from 10 x 10 x 0.5 mm coupons.

5. Similar testing (3 and 4) through the thickness of base metal will also be performed in collaboration with CRIEPI as part of the CNWG program with Japan.

6. Thermal annealing of these RPV materials may also be performed to compare with the same weld metal (WF-70) previously irradiated in test reactors & annealed.

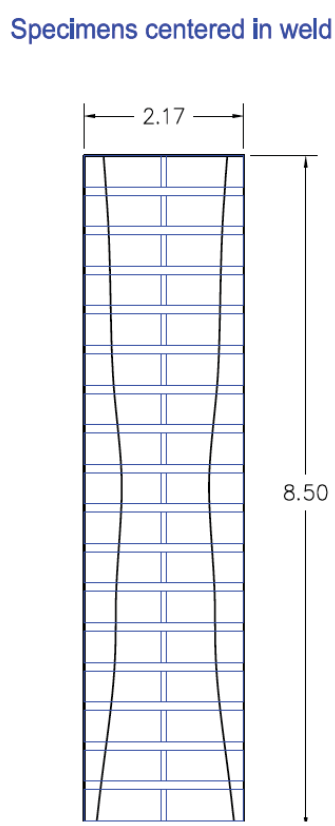


**Figure 16.** Detailed C block layout for Charpy Specimens. Figure derived from reference [2].

## 9. SUMMARY

This report documents the acquisition and shipment, by rail, of four segments of the Zion Unit 1 RPV to the Energy Solutions Memphis Processing Facility (MPF) for eventual laboratory testing. Specifically, only Segment 1 of the Zion Unit 1 RPV containing well-characterized base metal B7835-1 heat and a section of the well-characterized WF-70 beltline weld (between the lower and the intermediate shells) was harvested and shipped for cutting into blocks for machining into mechanical and microstructural characterization samples at a third vendor. Data from RPV surveillance specimens containing similar WF-70 weld materials are available in the literature for a comparison of hardening and changes in fracture toughness and microstructure [6-8]. Similarly, data from surveillance specimens containing B7835-1 plate material are available for a comparison of hardening and changes in fracture toughness [12]. Access to service-irradiated RPV welds and plate sections will allow through-wall attenuation studies to be performed, which will be used to assess current radiation damage models [1, 2].

## 10. REFERENCES


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